FABRICATION OF MOLYBDENUM FIELD EMISSION ARRAYS FOR A LOW EMITTANCE GUN USING SILICON MOULDS

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At the Paul Scherrer Institut, a field emission electron gun for application in a free electron laser is developed. This requires arrays of micro-scale tips for which we are developing a fabrication process. A silicon wafer with pyramidal etch pits is used as mould for deposition of molybdenum. To obtain mechanical stability, the molybdenum layer is reinforced by electroformed nickel. Removing the silicon mould reveals the tips which are 1.1 to 4.2 µm tall. Each array is formed by about 7600 tips on an area from 0.2 mm^2 to 1.8 mm^2 with a grid of 5 to 15 µm.

The design of an electron gun capable of producing a beam emittance one order of magnitude lower than current technology would considerably reduce the cost and size of a free electron laser radiating at 0.1 nm. Most of the current accelerators use either photocathodes or thermionic cathodes. An electron source based on field emission is an attractive alternative for a high brightness source since high current density beams (10^8A/cm^2) with small initial kinetic energy can be emitted.

Both, individual tips and field emitter arrays (FEAs) are studied at the Paul Scherrer Institut in the low emittance gun (LEG) project [1]. Among other approaches, FEAs have been fabricated from molybdenum using electron beam evaporation [2] and from diamond using a moulding technique [3].

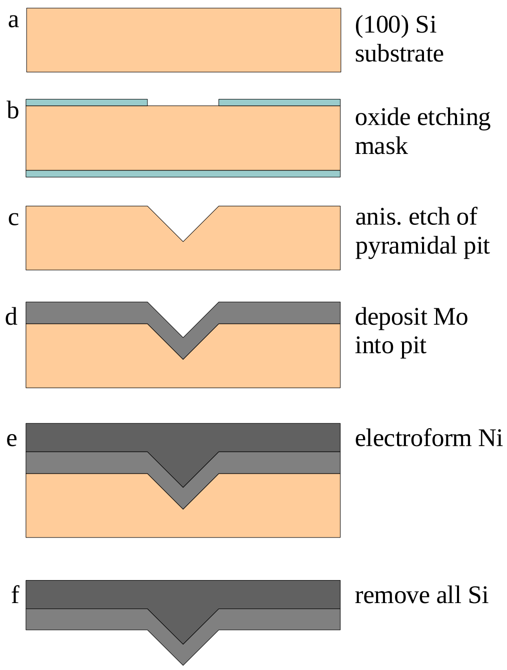

Fig. 1: Fabrication sequence for the FEA.

We are developing a moulding process for molybdenum FEAs. Fig. 1 illustrates the process sequence. The substrate for the mould is a (100) silicon wafer (Fig. 1a). As etch mask for the silicon etch, a 100 nm thick thermal oxide is grown and patterned with dry etching (Fig. 1b). An anisotropic silicon etch with KOH- solution is performed to define the pyramidal etch pits (Fig. 1c). Into those pits a 250 nm thick molybdenum layer is sputtered (Fig. 1d). To provide mechanical strength for the FEA, a 300 µm thick reinforcement layer of nickel is deposited by electroforming (Fig. 1e). The silicon mould is removed with wet etching and the tip array is revealed (Fig. 1f). Fig. 2 shows SEM images of a tip array.

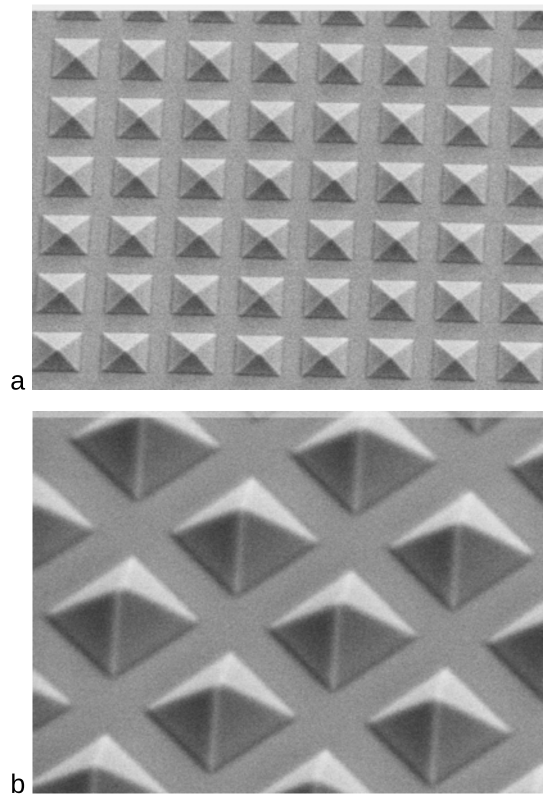

Fig. 2: SEM-images of a Mo tip array, tip height: 2.1 µm, grid: 5 µm.

As a next step, a metal gate layer has to be integrated. Due to the small dimensions of the tips, a self aligned process is being developed. Beside this moulding technique, development work on a Spindt-type process is underway.

REFERENCES

[1] R. Ganter et al., FEL2004, Trieste, Italy.

[2] C.A. Spindt, K.R. Shoulders, L.N. Heynick, US patent 3755704.

[3] W.P. Kang, J.L. Davidson, D.V. Kerns, US patent 6132278.